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Performance Testing of Oil Mop Zero Relative Velocity Oil Skimmer

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Performance Testing of Oil MOP Zero Relative Velocity Oil Skimmer

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A fast current (operating range up to 3 m/s (6 kts)), prototype skimmer was designed and built by OMI and delivered to the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) to be tested. The principle of operation was based on adsorbing oil onto oleophilic fibers woven into a rope. The rope and fibers were then squeezed by wringers to remove the oil into a recovery basin. The device was rigged, trimmed and then towed into a controlled oil slick while being operated and monitored for oil recovery. Device operating speed, oil slick thickness, tow speed, and wave conditions served as controlled independent variables. The fluid recovered was sampled during and after the test run to determine device performance. Results of the tests were evaluated in terms of recovery rate, recovery efficiency, and throughput efficiency (i.e., the amount and quality, or percent oil, of fluid recovered versus the amount of oil distributed). Because of adverse weather and problems with the device, the testing program was of short duration. Only a few tests were run, so parameters could not be completely optimized.

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PERFORMANCE TESTING OF OIL MOP ZERO RELATIVE VELOCITY OIL SKIMMER

by

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Contract No. 68-03-0490

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes performance evaluation tests of a research prototype skimmer based on an adaptation of existing commercial equipment. The principle shows promise of being able to perform effectively at relatively high speeds, thereby reducing cleanup time. This technique will be of interest to all those interested in cleaning up oil spills in inland and coastal waters. Further information may be obtained through the Resource Extraction and Handling Division, Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This research test program was initiated by the U.S. Environmental Protection Agency (EPA) and the U.S. Coast Guard (USCG) to determine the ability of the Oil Mop Inc. (OMI) zero relative velocity (ZRV) oil skimmer to recover oil from a water surface under various conditions.

A fast current (operating range up to 3 m/s (6 kts)), prototype skimmer was designed and built by OMI and delivered to the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) to be tested. The principle of operation was based on adsorbing oil onto oleophilic fibers woven into a rope. The rope and fibers were then squeezed by wringers to remove the oil into a recovery basin. The device was rigged, trimmed and then towed into a controlled oil slick while being operated and monitored for oil recovery. Device operating speed, oil slick thickness, tow speed, and wave conditions served as controlled independent variables. The fluid recovered was sampled during and after the test run to determine device performance. Tests were conducted in accordance with a test matrix developed by the USCG and EPA. Results of the tests were evaluated in terms of recovery rate, recovery efficiency, and throughput efficiency (i.e., the amount and quality, or percent oil, of fluid recovered versus the amount of oil distributed). Because of adverse weather and problems with the device, the testing program was of short duration. Only a few tests were run, so parameters could not be completely optimized.

This report was submitted in fulfillment of Contract No. 68-03-0490, Job Order No. 29, by Mason & Hanger-Silas Mason Co., Inc., under the sponsorship of the U.S. Environmental Protection Agency and the U.S. Coast Guard. This report covers the period from November 29, 1976, to December 3, 1976, when work was completed.

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ABBREVIATIONS AND SYMBOLS

C	--Centigrade
cm	--centimeter
EPA	--Environmental Protection Agency
F	--Fahrenheit
ft	--feet
gal	--gallon
gpm	--gallons per minute
H.C.	--harbor chop
H,L,T	--height, length, period
in.	--inch
kt	--knot
m	--meter
mm	--millimeter
min.	--minute
N	--Newton
OMI	--Oil Mop, Incorporated
OPT	--optimum
ppt	--parts per thousand
s	--second
Sun or Sunvis	--Sun Oil Company registered brand names
TBD	--to be determined
USCG	--United States Coast Guard
VDU	--Vacuum Distillation Unit
ZRV	--Zero Relative Velocity

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SECTION 1

INTRODUCTION AND OBJECTIVES

Oils are being handled by marine transportation and dockside equipment in increasing amounts and variety. The growing potential for accidental discharge of these materials poses a serious threat to the welfare of the general public and environment.

Satisfactory devices for both control and cleanup of oil spills are still in the developmental stage. For cleanup, a device must be efficient, easy to deploy and operate, and able to perform under many environmental conditions.

Oil Mop Inc. (OMI) has designed a new fast-current skimmer system using endless-rope sorbent mops to adsorb spilled oil from the water's surface. The moving skimmer processes the mops at about its own speed, maintaining zero relative velocity (ZRV) between the rope mops and the oil layer. The device has been tested at the U.S. Environmental Protection Agency's (EPA) oil and hazardous materials simulated environmental test tank (OHMSETT) facility, which was specifically designed to test prototype oil control and cleanup equipment under simulated hydrodynamic environmental conditions.

The purpose of this project was to evaluate the performance of the prototype OMI-ZRV fast-current skimmer at tow speeds up to 2.54 m/s (5 kt) with Sunvis 7 and Sunvis 1650 oils under several wave conditions. But freezing conditions resulted in lengthy start-up and shake-down times; therefore Sunvis 1650, the heavier oil, was not tested. Since the principle of operation of the device required the velocity of the oil mops to be relatively close to the tow speed, the maximum tow speed was limited by the maximum mop speed. And because of the lack of drive power in the oil mop engines, the maximum tow speed tested was 1.78 m/s (3.5 kt). This test was conducted with the rope-mop speed at 1.52 m/s (3.0 kt).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn from the evaluation of the test data and observations of equipment performance.

The OMI-ZRV skimmer recovered oil best at slow speeds (1.02 m/s (2 kt)) in calm water with the belt running slightly faster or slower than the tow speed. But before a definite appraisal of the system can be made, several items support the need for further testing:

1. Because of initial set-up problems, weather conditions, and problems with the device, only two days of testing were possible. Consequently, there was no chance to analyze the data collected and refine testing techniques.

2. The device's recovery efficiency improved toward the end of each test run, suggesting that the samples were collected too early in the test runs and before steady state conditions were achieved.

3. Recovery time was not recorded until the second day of testing; it was noticed then that a discrepancy (< 15 seconds) could exist between it and distribution time.

4. A definite time for starting the rope mops could not be established. Such unknowns make design analysis difficult.

The design shows promise but is still in the developmental stage. The rope-mop and squeezer components of the skimmer have been used successfully to recover oil from water at a fixed location with little or no current. Successfully incorporating these components into a moving system will require further study and modifications of the present device. Such modifications should include a different shape for the catamaran hulls and larger rope-mop drive engines. Gradual transition between the main hull to the bow and stern would produce less headwave, less drastic oil channeling, and less entrainment of missed oil after the device passes. The rope-mop drive units used during testing could not process the rope mops fast enough and sometimes stalled during operation. These and other modifications are included under Results and Discussion.

SECTION 3

TEST APPARATUS DESCRIPTION

DEVICE DESCRIPTION

The OMI-ZRV skimmer was mounted on a 2.74-m (9-ft) wide aluminum catamaran that was fitted with modified bows (Figures 1 and 2). The craft was rigged and towed during this testing, but it can be equipped with two outboard motors with steering controls. Two Mark II-9D mop engines with wringer assemblies drove and wrung six oil mops. Each engine was equipped with an oil collection pan, vertical guide idlers, four rollers, and two adjustable springs for setting pressure on the wringers. The drive on the Mark II-9D series mop engine consisted of a positive chain drive going to one of the 22.86-cm (9-in.) polypropylene rollers from a reduction gear. The rope mops were constructed of thin, flat, oleophilic plastic fibers woven into a plastic rope base. The fibers formed a thick nap along the entire length of the rope, which floated on the oil/ water interface.

The six oil mops used on the device were each 22.86 cm (9 in.) in diameter and about 15.24 m (50 ft) long. The continuous lengths of rope mop were laid on the water beneath the center of the catamaran and pulled on board at the stern to be squeezed by the wringers before being returned to the water's surface.

VIDEO AND PHOTOGRAPHIC DOCUMENTATION

Cameras provided visual documentation of test layout, equipment, and performance characteristics. A black-and-white TV camera in a waterproof case provided underwater video, which was recorded on 2.54-cm (1-in.) video tape using a recording deck. Topside and tank-side window coverage was provided by two 16-mm movie cameras and a 35-mm slide camera.

TACHOMETER DESCRIPTION

A magneto tachometer was mounted on the frame of a Mark II-9D engine (Figure 3). A similar tachometer to measure the bridge speed was mounted on the axle of the bridge wheel. The output of each tachometer went into a differential voltmeter for measuring the relative velocities between bridge speed and rope-mop speed. A separate voltmeter measured the rpm of the 22.86-cm (9-in.) diameter squeegee roller, from which rope-mop speed could be directly determined.

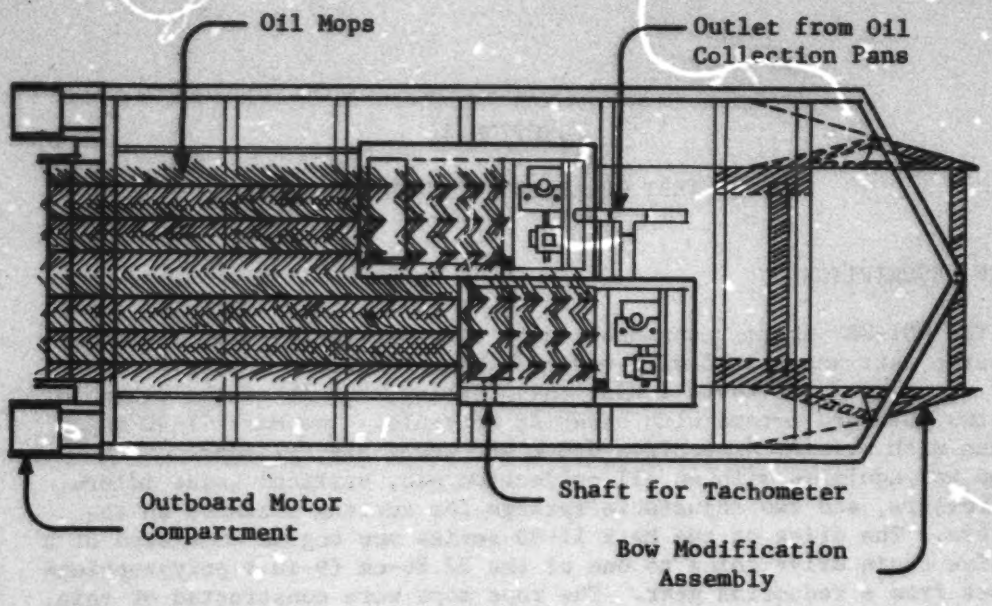

Figure 1. Top view of the OMI-ZRV skimmer.

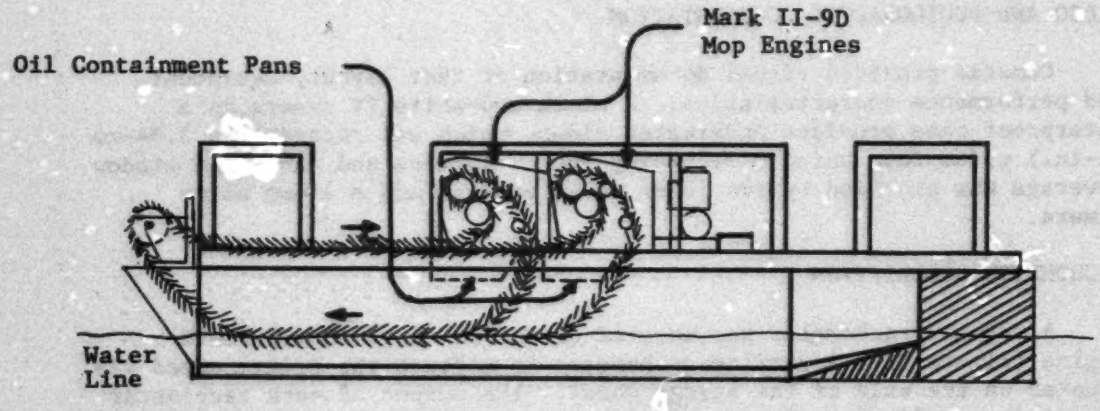

Figure 2. Side view of the OMI-ZRV skimmer.

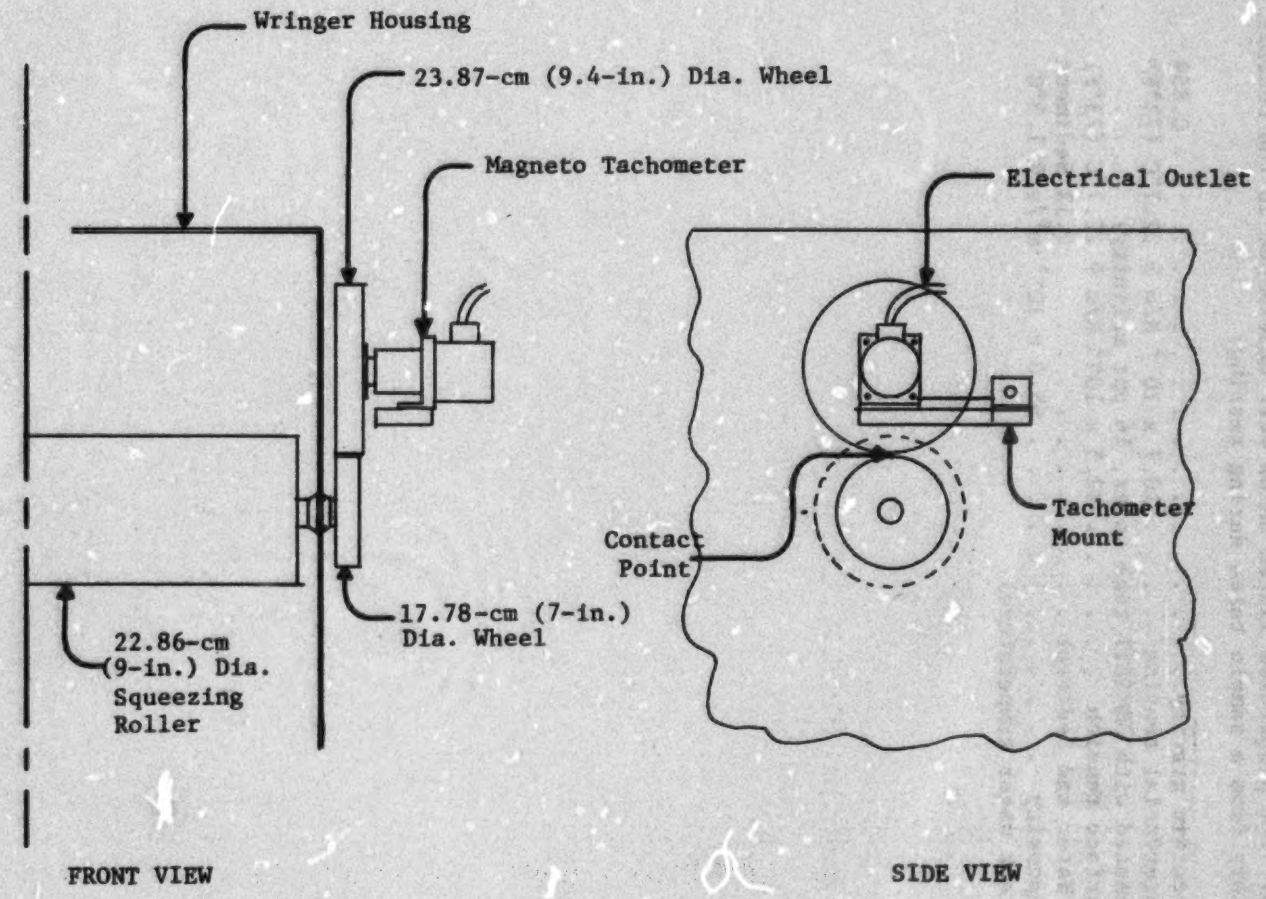

Figure 3. Schematic diagram of the tachometer and reduction wheels.

TEST FLUID DESCRIPTION

Sunvis 7 oil was the sole test fluid distributed during the test program. The properties listed below were determined in the OHMSETT laboratory from a sample taken during testing:

Specific gravity	0.859
Interfacial tension	10.7×10^{-3} N/m @ 22.7°C (73°F)
(tested with OHMSETT tank water, 16 ppt salinity)	
Surface tension	32.5×10^{-3} N/m @ 22.7°C (73°F)
% Water and Sediment	0.1% Sediment
Viscosity	65.0×10^{-6} m^2/s @ 1.5°C
(tank water temperature)	

SECTION 4

TEST PLAN AND PROCEDURES

TEST RATIONALE

To fully evaluate and optimize device performance within the given test time, a test matrix was developed to determine the optimum value for a given parameter (Table 1), fix it there, and then test variations of a second parameter. Tests with subsequent parameters were conducted in a similar fashion. Because of time and weather conditions, some parameters could not be investigated fully for optimization.

The tests were concerned with measuring the steady state or equilibrium performance of the OMI-ZRV skimmer. Steady state testing was qualitatively identified by visual observations during the tests. The fluid collected by the device was continuously offloaded during a test. When the color of this stream exiting the dump valves became consistent, steady state was declared, and the fluid was collected.

At the end of a test run, the quantity of oil/water mixture collected was measured, and the quality (% oil) was determined through laboratory analysis. Oil recovery rate, throughput efficiency, and recovery efficiency were then calculated (Table 2).

PROCEDURES

All performance testing was conducted at OHMSETT by the operating contractor, Mason & Hanger-Silas Mason Co., Inc., with the guidance of the OMI personnel. Figure 4 shows a general view of the test set-up and personnel involvement.

Test fluid contained on the main towing bridge was pumped through a manifold and nozzle system for distribution onto the water's surface approximately 15.2 m (50 ft) forward of the test device. To ensure that the oil did not mix into the water column upon delivery, a splashpan was used with the nozzle system and a smooth slick was laid on the water surface. To ensure a high percentage of encounter, 1.9-cm (0.75-in) diameter polypropylene guide ropes were used to contain and direct the oil into the device. Oil thicknesses were calculated from the speed of tow, encounter width, and distribution rate.

A test run required that proper procedures were followed before, during, and after the test. The rope mops were brought up to the desired speed with the off-loading pumps operating and the dump valves open.

TABLE 1. USCG - EPA OIL MOP TEST MATRIX (Proposed).

Test no.	Oil type	Tow speed	Oil* thick mm	Dist. rate x($10^{-3}m^3/s$)	Wave	Belt speed	Tension	Wave Generator Stroke cm	RPM	Wave H,L,T m,m,s
1-1	Sun 7	1.0	3	4.16	Calm	ZRV	Initial			
1-2	Sun 7	1.5	3	6.24	Calm	ZRV	Initial			
1-3	Sun 7	2.0	3	8.33	Calm	ZRV	Initial			
1-4	Sun 7	2.5	3	10.41	Calm	ZRV	Initial			
2-1	Sun 7	OPT	3	TBD	Calm	-	Initial			
2-2	Sun 7	OPT	3	TBD	Calm	+	Initial			
2-3	Sun 7	OPT	3	TBD	Calm	OPT	-			
2-4	Sun 7	OPT	3	TBD	Calm	OPT	+			
3-1	Sun 7	1.0	3	4.16	0.6 m*	OPT	OPT	7.6	35	
3-2	Sun 7	1.5	3	6.24	0.6 m	OPT	OPT	7.6	35	
3-3	Sun 7	2.0	3	8.33	0.6 m	OPT	OPT	7.6	35	
3-4	Sun 7	2.5	3	10.41	0.6 m	OPT	OPT	7.6	35	
4-1	Sun 7	2.5	3	10.41	Reg 1	OPT	OPT	11.4	30	0.5, 5.2, 1.9
4-2	Sun 7	2.5	3	10.41	Reg 2	OPT	OPT	51.2	24	0.42, 10.7,2.7
4-3	Sun 7	2.5	3	10.41	Reg 3	OPT	OPT	19.0	15	0.36, 20.1,4.6
5-1	Sun 7	OPT	5	TBD	Calm	ZRV	Initial			
5-2	Sun 7	OPT	8	TBD	Calm	ZRV	Initial			
6-1	Sun 1650	1.0	3	4.16	Calm	ZRV	Initial			
6-2	Sun 1650	1.5	3	6.24	Calm	ZRV	Initial			
6-3	Sun 1650	2.0	3	8.33	Calm	ZRV	Initial			
6-4	Sun 1650	2.5	3	10.41	Calm	ZRV	Initial			
7-1	Sun 1650	1.0	3	4.16	0.6 m	ZRV	Initial	7.6	35	
7-2	Sun 1650	1.5	3	6.24	0.6 m	ZRV	Initial	7.6	35	
7-3	Sun 1650	2.0	3	8.33	0.6 m	ZRV	Initial	7.6	35	
7-4	Sun 1650	2.5	3	10.41	0.6 m	ZRV	Initial	7.6	35	

+, - Slight increase or decrease in belt speed or tension from initial setting
* Harbor chop

TABLE 2. TEST RESULTS: OIL HOP INC., MARK II-9D Skimmer (Sunvis 7 light oil).

Test no.	Tow speed m/s	Wave cond.	Dist. vol. m^3	Dist./Rec. time/time sec/sec	Dist. rate $x(10^{-1}m^3/s)$	Slick thick. mm	Hop speed m/s	% Enc.	Discrete samples: Sam. A % oil	Discrete samples: Sam. B % oil	Performance characteristics: Oil rec. m^3	Oil rec.* rate $x(10^{-1}/m^3/s)$	Rec.* eff. %	Throughput* efficiency %
1-2	1.54	Calm	0.50	59.8	8.39	3	1.54	100	4.7	12.6	0.047	0.78	8.7	12.4
2-1	1.78	Calm	0.50	50.0	10.03	3	1.54	100	20.9	27.3	0.102	2.04	24.1	27.2
2-2	1.27	Calm	0.44	60.2	7.23	3	1.54	100	20.6	24.8	0.117	1.94	22.7	35.8
5-1	1.54	Calm	0.82	60.6/56.8	13.58	5	1.54	100	17.4	29.7	0.088	1.55	23.6	14.2
3-1	1.03	0.6 m HC+	0.35	60.1/63.6	5.76	3	1.03	90	10.2	19.4	0.084	1.32	14.8	35.5
3-2	1.54	0.6 m HC	0.50	60.2/50.0	8.24	3	1.54	85	10.5	10.2	0.066	1.33	10.4	20.7
5-1R	1.54	Calm	0.83	60.0/48.2	13.91	5	1.54	90	18.1	21.3	0.104	2.15	19.7	18.6
5-2	1.54	Calm	1.39	59.7/62.8	23.21	8	1.54	95	17.5	30.6	0.132	2.11	24.1	13.3

*See Appendix A for definition.
+Harbor chop.

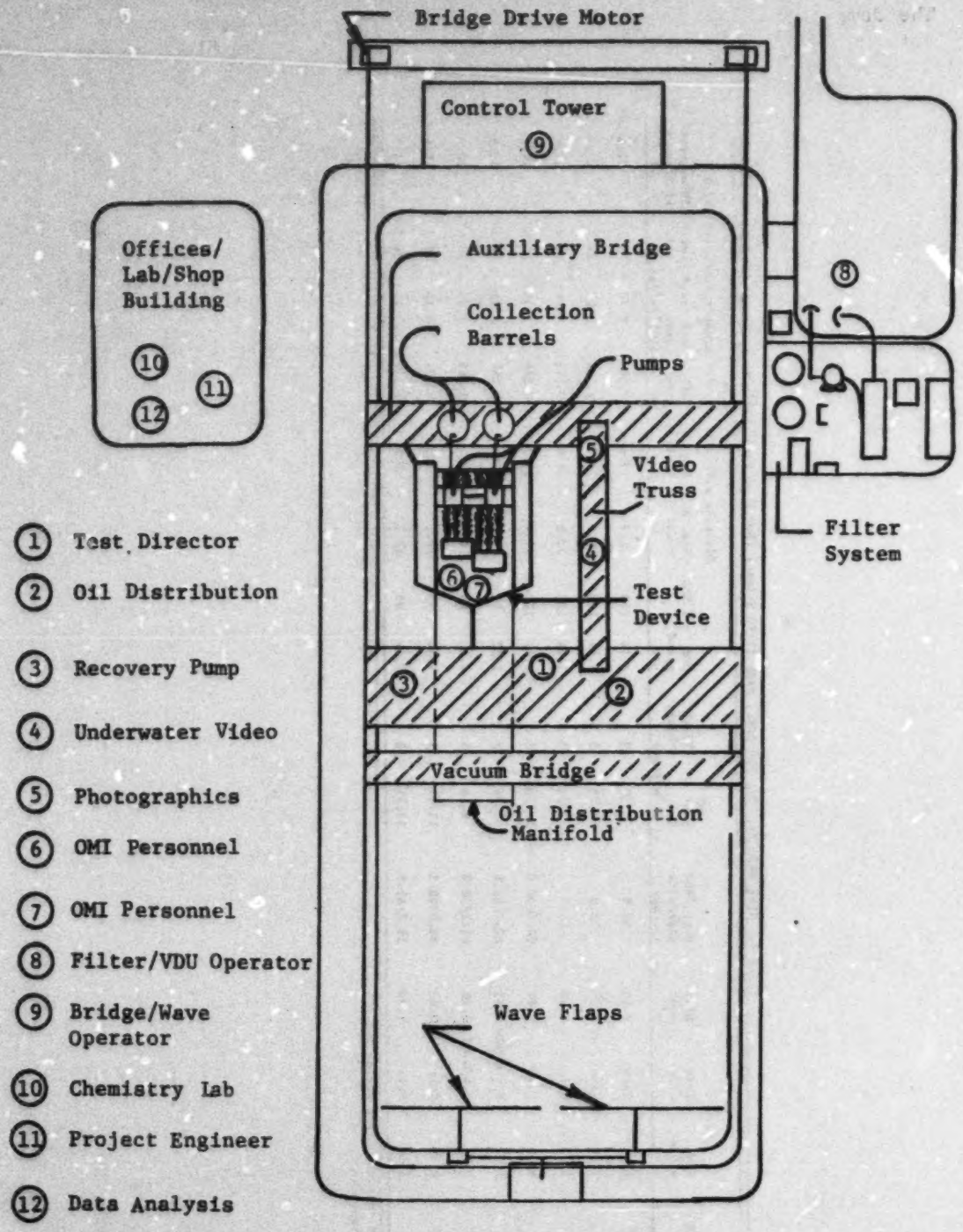

Figure 4. Test set-up for the OMI-ZRV skimmer.

The bridge was brought to speed, and then oil distribution was begun. The dump valves were closed when it was seen that the pumps were pumping not just water but a consistent oil/water mixture. The fluid was then pumped from the device to collection barrels on the auxiliary bridge. Recovery efficiency samples were taken from near the pumps' discharges at the midpoint and near the end of the test run. Oil was distributed for about 1 min. for each test run. After the device passed over the end of the slick, the rope mops were stopped and the bridge brought to a halt. The oil containment pans were then flushed with 19 liters (5 gal) of water, and pumping was continued until the pans were empty. The amount of sample collected was determined by measuring the fluid height in the collection barrels and converting that height into volume. Thirty minutes were allocated for oil/emulsion/water separation by gravity. The water was then drained, and the remaining oil/emulsion height measured. A sample was taken from the emulsion layer for laboratory analysis. The remaining oil/emulsion was mixed for 5 min. and then sampled again. Each collection barrel was measured and sampled similarly. Data taken during the tests were: test number, date, time, tow speed, rope-mop speed, oil distribution rate, oil distribution time, recovery time, wave condition, and type of oil.

Problems encountered with the weather and the device prevented the above-mentioned procedures from going smoothly. The two main factors were the ice that formed on the rope mops overnight and the inability of the wringers to consistently drive the full complement of ice-free rope mops at speeds exceeding 1.5 m/s (3 kt). In the morning, the rope mops had to be broken free of the ice that formed in the deck trays. Sometimes not all of the ice was removed from the nap of the rope. This ice would catch in the wringer and delay or interrupt a test. By afternoon, the ice was removed completely, but the drive engines could not readily engage the rope mops immediately. They had to be coaxed up to speed by running the mops in water, thus wringing and throwing any precharge of oil out of them. During a test, the drive engines would occasionally slow or be slowed to prevent stalling.

SECTION 5

RESULTS AND DISCUSSION

Because of the short test time and amount of data available, the OMI-ZRV skimmer must be examined qualitatively. Eight oil-collection test runs were made over 2 days. Two of those runs were subjected to steady state interference such that the data collected were non-representative of the device capability. Test run 1-2 was made before the catamaran was adequately trimmed. Under tow, the craft nosed down sufficiently to dip the forward cross member into the oil slick and create turbulence. Oil entrainment into the water column occurred before the rope mops contacted the oil slick. During test run 5-1, the rope mops were slowed down and sped up continuously to prevent engine stall. This probably occurred because it was the first run of a cold day after a very cold night during which ice had formed on the rope mops. Near the end of the test, the far port-side rope mop parted, and that engine was stopped. The 5-1 test run was repeated; 1-2 was not.

Some difficulties were discovered during testing that affected the analysis. Recovery time was not recorded until the second day of testing, where a discrepancy was noted between it and distribution time. Also, a definite time for starting the rope mops could not be established. Such unknowns make quantitative design analysis difficult.

DEVICE DISCUSSION

The contact/collection area beneath the catamaran was not adequately covered by the rope mops or protected from the wake developed by the bows. Even with the bow modifications, enough wake was produced to channel the oil to the center of the device. This effect proved disadvantageous because the rope mops were divided into two groups of three each. One group was driven and wrung by the port oil mop engine and the other by the starboard engine. The inner mops of the two groups were separated about 38.5 cm (15 in.), centerline to centerline, upon coming over the stern roller and returning to be wrung. A good deal of oil escaped down between the groups of oil mops, either because of poor oil/rope-mop contact or inadequate oil retention power of the inner most rope mops. Hardly any oil was left on the port or starboard sides beneath the craft after the slick reached the stern. The outboard rope mops appeared to contribute only water to the collection pan, as was evidenced by the color of the "rooster tails" that sprayed up from the rope mops as they came over the stern roller. The outer sprays were white, but the center ones were a dark pink from the dyed oil. Throughput

efficiency for each test run was calculated based on 75% rope-mop coverage of the area beneath the catamaran. With the bow wave, perhaps this percentage is sufficient, but the center area should have the greatest coverage.

Observation of the tests from the underwater window revealed that the unrecovered oil was entrained well into the water after the device passed. If the catamaran had been propelled with the optional outboard motors, entrainment would have been more severe.

The drive motors should be larger to improve rope-mop handling capability and increase rope-mop speed above 1.54 m/s (3 kt). Ice that formed on the rope mops had to be removed largely by hand before the motors could be coaxed into completing the job. Only then could testing resume. New rope mops could not be processed until they were run singularly through the wringer for flattening. Occasionally during testing, the motors would nearly stall, so the speed of the mops would be decreased and then brought up again to keep them running.

Before additional testing, the skimmer should be trimmed properly. Weights were placed in the outboard motor compartments, and a towing bracket was fabricated to prevent the device from nosing down under tow. During the first test, the front cross member of the catamaran made contact with the oil slick.

The oil collection pan beneath the port wringer would not drain as rapidly as the starboard pan. Thus the pump sucked air from the empty pan rather than fluid from the full pan. The loss of oil overflowing the full pan was minimal-- about 7.6 liters (2 gal)-- because the device recovery time was only 1 min. Longer operation would drastically increase the loss, because the overflow began near the end of the test run. The collection pans should not be drained to a "Y" coupling and pumped from there. Two separate drains or one collection pan should be used.

A catch-basin on the stern of the catamaran should be installed to recover the fluid that is flipped from the rope mops as they travel over the stern roller and head toward the wringers.

In the future, the rope mops should be installed before the testing at the correct lengths. Trial and error adjustments in rope-mop length required over half a day in tank time, and the adjustments, which required finger dexterity to tie and untie the wet rope, had to be done in subfreezing temperatures.

OPERATION DISCUSSION

The rope mops should not be run before the oil slick passes beneath the device. Continuously running the rope mops in water and wringing them strips the necessary precharge of oil from the fibers and loads the collection pans with water. This effect is evidenced by the oil slick distributed by the rope mops after the end of the distributed oil slick is behind the device. In such an instance, oil is lost to the water

from the rope mops. When a non-precharged rope mop encounters an oil slick, time is required to displace the water and develop a sufficient oil film on the fibers. Evidence of this fact exists in the increase of oil content shown in the second discrete sample over the first. Running the rope mops slightly slower or faster than ZRV should be examined more closely. The data indicate that such operation improves performance. Such improvement would stand to reason because the oil would be forced onto the fibers and into apertures too small for the oil to enter on its own accord.

Maximum recovery efficiency was possibly never reached in testing. An increase in the percentage of oil collected was noticeable in the discrete samples taken toward the end of the test runs. The average increase was 28% (discounting tests 5-1 and 1-2) over a period of about 30 s. Even that oil percentage was still low (≈20%) and probably would have increased somewhat if longer runs had been made. This result indicates that a precharge of oil is necessary on the rope mops.

DATA ANALYSIS

A qualitative data analysis (Figures 5, 6, and 7) discloses the following trends peculiar to the device operating under the given conditions.

Recovery Rate

1. The recovery rate did not appear affected by towing the device slower or faster than the belt speed. Thus specific factors must be examined further before a trend can be identified. These factors could have individually affected device performance and thus possibly interacted to cancel or complement each other. They are: (a) greater oil encounter rate was seen by the device at the faster-than-ZRV tow speed in order to maintain slick thickness (positive effect); (b) more fibers were processed for a given volume of oil at the slower-than-ZRV tow speed (positive effect); (c) a greater wake was produced at the faster-than-ZRV tow speed, which left less oil to contact the outboard rope mops (negative effect); and (d) one or more of the previous conditions could give the rope mops the necessary and sufficient precharge more quickly and thus increase efficiency (positive effect).

2. The recovery rate did not appear to be affected by tow speed in a harbor chop condition. The wave condition alone appeared to affect recovery rate. The change in slick thickness at 1.54 m/s (3 kt) in calm water did not drastically alter results, while a slightly shallower slick in waves did. A similar test in calm water is needed to confirm whether the wave condition caused the change or the rope mops were at their saturation level in a 5 mm slick.

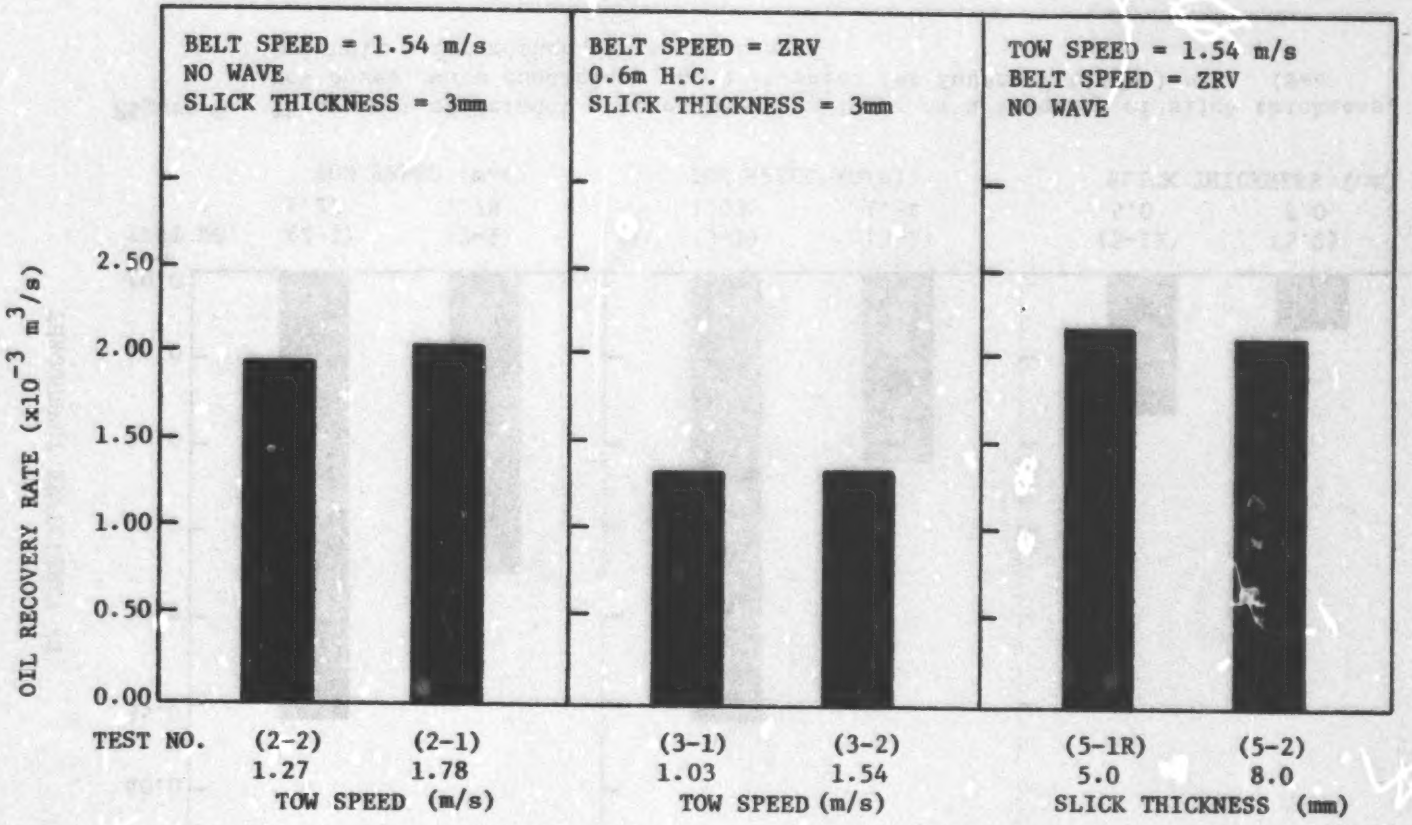

Figure 5. Oil recovery rate of the OMI-ZRV skimmer as a function of slick thickness, tow speed, wave condition, and belt speed for Sunvis 7 (light) oil.

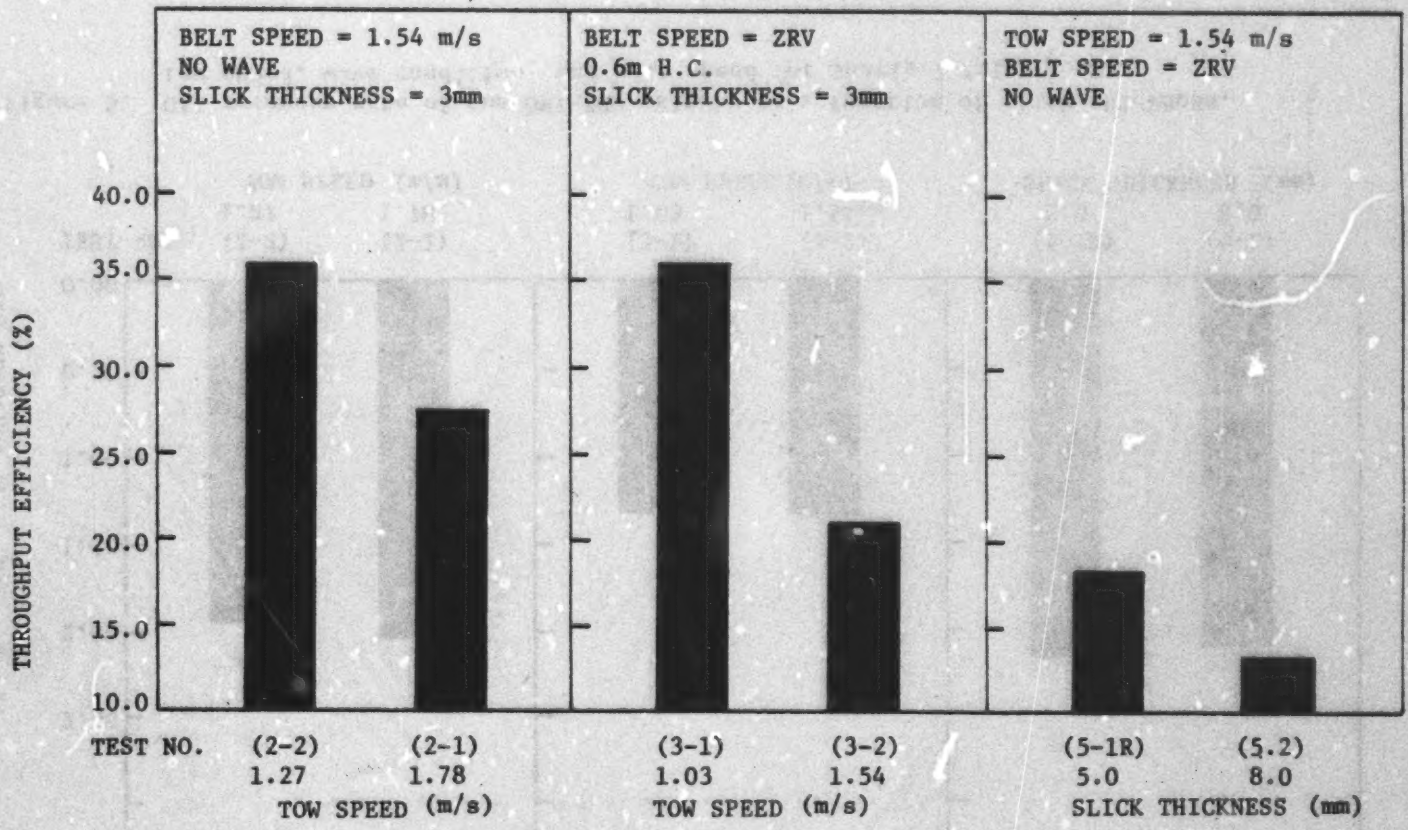

Figure 6. Throughput efficiency of the OMI-ZRV skimmer as a function of slick thickness, tow speed, wave condition, and belt speed for Sunvis 7 (light) oil. (See Appendix A for method of calculation).

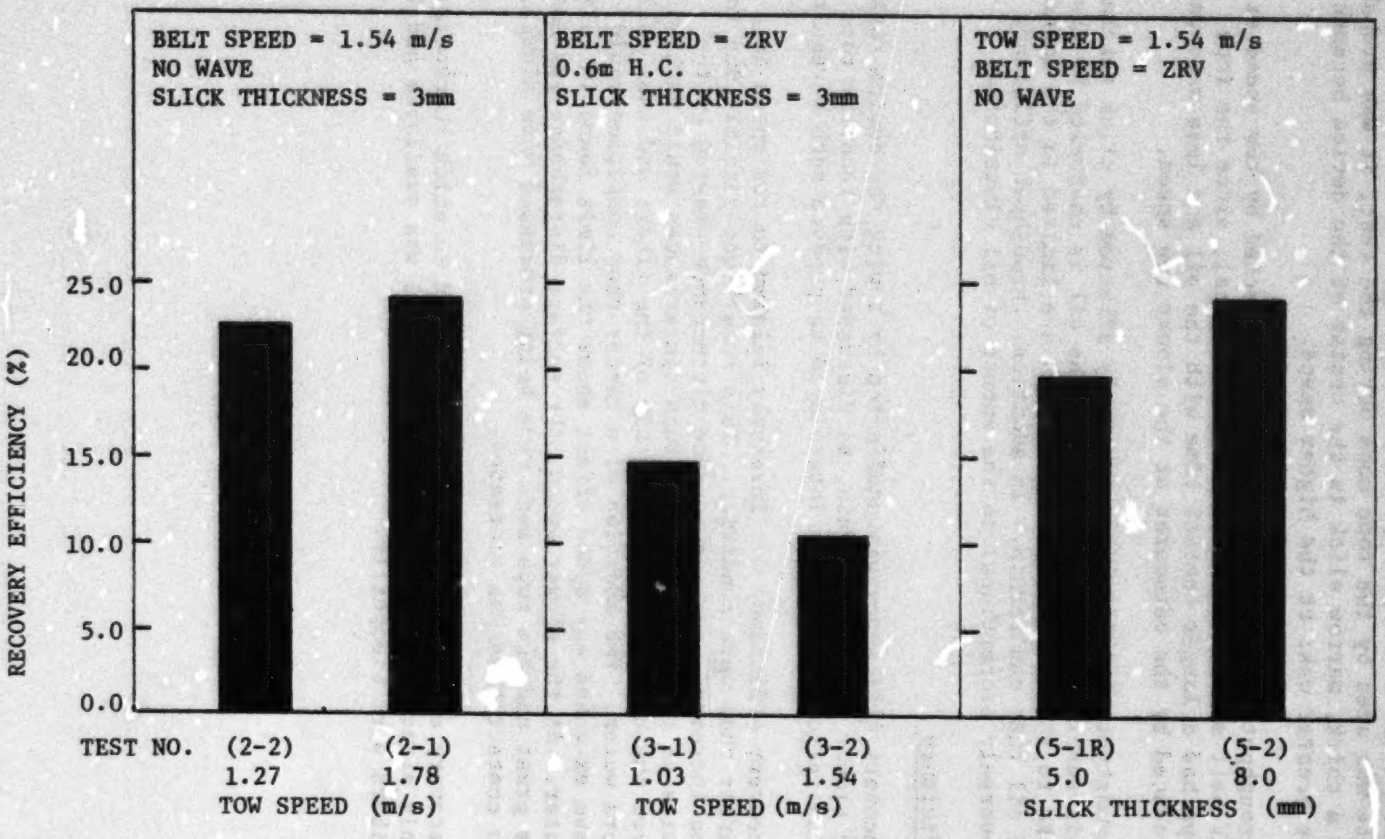

Figure 7. Recovery efficiency of the OMI-ZRV skimmer as a function of slick thickness, tow speed, wave condition, and belt speed for Sunvis 7 (light) oil.

Throughput Efficiency

1. Throughput efficiency decreased when the device was towed faster than the rope-mop speed. Although a greater oil encounter rate was seen by the rope mops during the test, it was probably in a thick, narrow slick in the center of the device because of the greater wake at the higher speed.

2. Throughput efficiency was inversely affected by tow speed at ZRV belt speed. This effect seems logical, since the rope mops had a longer contact time with the oil and less wake was produced by the catamaran at the slower tow speed.

3. Throughput efficiency was inversely affected by slick thickness. This result is reasonable, since the oil is channeled by the wake to the center rope mops, which are limited in the amount of oil they can retain. In addition, throughput efficiency is inversely proportional to the amount of oil distributed.

Recovery Efficiency

1. Recovery efficiency was unaffected by towing the device faster or slower than ZRV. Again, as discussed with recovery rate, many factors could have interplayed to produce such a result.

2. Recovery efficiency was inversely related to tow speed in a harbor chop wave condition. This result was possibly due to the increased wake and surface disturbance created by the hulls at the higher speed. Such disturbances would wash water over the rope mops, exposing all of the fibers and thus collecting more water. The addition of a harbor chop condition would have extended any speed effect above the limit found in calm water. At the slower speed, the surface disturbance was not as great and the rope mops were being processed more slowly, so contact time was increased.

3. Recovery efficiency was directly related to slick thickness. This effect is reasonable since more oil was available and the fibers were oleophilic.

APPENDIX A

EQUATIONS AND DEFINITIONS

1. Oil Recovery Rate (m^3/s)

Procedure A -

$$O.R.R. = \frac{\text{oil recovered}}{\text{oil distribution time}}$$

*Procedure B -

$$O.R.R. = \frac{\text{oil recovered}}{\text{recovery time}}$$

2.** Throughput Efficiency (%)

$$T.E. = \frac{\text{oil recovered}}{(\text{oil distributed})(\%\text{enccounter})(.75)}$$

3. Recovery Efficiency (%)

$$R.E. = \text{\% oil content in samples taken at pump discharge}$$

*Recovery Time - time from the first contact of oil with the mop to the last. This definition was used for test 5-1 and following tests.

**Based on 9-in. mop diameter x 6 mops = 54 inch coverage width.

$$\frac{\text{54 inch mop coverage}}{\text{72 inch hull separation}} = .75$$

APPENDIX B

FACILITY DESCRIPTION

The OHMSETT facility, owned by the U.S. Environmental Protection Agency, is located in Leonardo, New Jersey. The facility provides an environmentally safe place to test and develop devices and techniques for the control and cleanup of oil and hazardous materials spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203.3 m (667 ft) long by 19.8 m (65 ft) wide, and a water depth of 2.44 m (8 ft). The tank can be filled with fresh or salt water. It is spanned by a towing bridge that can tow loads up to 15,400 kg (34,000 lb) at speeds up to 3.05 m/s (6 kt) for a duration of 45 s. Slower speeds yield longer test runs. The towing bridge is equipped to lay test fluid on the surface of the water several feet ahead of the device being tested, such that reproducible thicknesses and widths of slicks can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator, absorber beach, and filter system. The wave generator and absorber beach can produce regular, minimum-reflection waves up to 0.61 m (2 ft) high and 24.38 m (80 ft) long, as well as a series of reflecting, complex waves meant to simulate the water surface of a harbor or estuary. The water is clarified by recirculation through a 0.13 m^3/s (2,000 gal/min) diatomaceous earth filter system. Clarification permits underwater photograph and video imagery, and removes the hydrocarbons that enter the tank during testing. The towing bridge has a built-in skimming board that moves expended test fluid to the north end of the tank for cleanup and recycling.

Tests at the facility are supported from a 650-m^2 (7,000-ft^2) building adjacent to the tank. This building houses offices, a quality control laboratory (for test fluids and tank water), a small machine shop, and an equipment preparation area.

The government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a staff of eleven multidisciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology and overall project direction.